

Society of Nuclear Medicine Procedure Guideline for Tumor Imaging Using F-18 FDG

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Authors: Heinrich R. Schelbert, MD, PhD (UCLA School of Medicine, Los Angeles, CA); Carl K. Hoh, MD (UCLA School of Medicine, Los Angeles, CA); Henry D. Royal, MD (Mallinckrodt Institute of Radiology, St. Louis, MO); Manuel Brown, MD (University of Pittsburgh Medical Center, Pittsburgh, PA); Magnus N. Dahlbom, PhD (UCLA School of Medicine, Los Angeles, CA); Farrokh Dehdashti, MD (Mallinckrodt Institute of Radiology, St. Louis, MO); and Richard L. Wahl, MD (University of Michigan Medical Center, Ann Arbor, MI).

I. Purpose

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting, and reporting the results of 18-fluoro-2-deoxyglucose (FDG) imaging in the evaluation of patients with suspected malignant disease, for the staging of malignant disease, or for the monitoring of therapy.

II. Background Information and Definitions

There is a growing body of evidence for the use of FDG in the differentiation of malignant from benign disease, staging and grading of malignant disease, differentiating recurrent or residual disease from therapy induced changes, and monitoring the response to therapy.

Depending on the clinical question and type of equipment available, the FDG imaging procedure may include:

- A. Limited Field Tomographic Images: usually performed when critical abnormalities are likely to be localized in a known region of the body (e.g. probable lung carcinoma, evaluation of hilar lymph node involvement).
- B. Dynamic Tomographic Images: consist of multiple sequential three dimensional images in a limited field. This type of acquisition is often used when quantitation of regional metabolic rates is needed.
- C. Whole Body Tomographic Images: usually performed to survey the entire body in the search for areas of abnormal FDG accumulation.
- D. Attenuation Correction: the method for correcting emission photon attenuation by either:
 1. Transmission Imaging: A set of corresponding images are acquired with an external source of radiation. Typically, these images are acquired with PET.

2. Mathematical Attenuation Correction: typically used in brain imaging, where an estimated attenuation correction based on the emission data may be used instead of actually acquiring transmission data.
3. Hybrid Attenuation Correction: This method consists of a short (approximately 2 min) transmission measurement, followed by an image segmentation to generate a calculated attenuation map.

III. Common Indications

- A. Differentiation of benign from malignant lesions
- B. Staging of malignant disease
- C. Grading of malignant brain lesions
- D. Differentiation of recurrent or residual malignant disease from therapy-induced changes
- E. Monitoring the response to therapy

IV. Procedure

- A. Patient Preparation
 1. Pre-arrival
Patients fast for at least 4 hr to diminish physiologic glucose utilization and to reduce serum insulin levels to near basal levels, and thus diminish FDG uptake by organs such as the heart. Some institutions require a GoLyte[®] prep the night before PET imaging to reduce bowel activity.
 2. Pre-injection
 - a. For brain imaging, for several min before FDG administration and during the uptake phase of FDG, the patient should be in a quiet and darkened room.
 - b. The blood glucose level may be checked prior to the FDG administration. Tumor uptake of FDG is reduced in hyperglycemic states.

Radiation Dosimetry in Adults

| Radiopharmaceutical | Administered Activity | Organ Receiving the Largest Radiation Dose* | Effective Dose* |
|--------------------------------|-----------------------|---|-----------------|
| | MBq (mCi) | mGy (rad) | mSv (rem) |
| 18-fluoro-2-deoxyglucose (FDG) | 350 – 750 i.v. | 0.17 bladder | 0.027 |
| | (10 – 20) | (0.63) | (0.10) |

*Per MBq (per mCi)

¹ICRP 53, page 76

B. Information Pertinent to Performing the Procedure

1. recent surgery (up to 6 mo), recent chemotherapy, radiation therapy, diagnostic procedures
2. history of diabetes, fasting state
3. patient's ability to lie still for one to two hours, or may require sedation
4. patient's ability to put his/her arms overhead

C. Precautions

None

D. Radiopharmaceutical (see Tables)

E. Image Acquisition

1. Acquisition parameters for FDG imaging with dedicated PET scanners:

- a. Limited Field Tomographic Images: used to not clearly delineate metabolic activity in lesions detected on physical examination and/or with other imaging modalities such as radiographs, CT or MRI. The addition of a *dynamic acquisition* may allow quantification of metabolic rates of tumors. Since the field of view is limited, accurate and careful patient positioning is critical for adequately including the suspected lesions in the tomograph's field of view.

Transmission images are acquired. Acquisition times and total counts collected

may vary between PET systems. Some institutions acquire transmission images of about 125 million counts over 15 to 20 min. Additionally, some imaging systems permit acquisition of the transmission images after injection of radiotracer before or after collection of emission images.

Intravenous injection of the radiopharmaceutical at a site contralateral to the site of concern is followed by the acquisition of the emission images beginning about 30–60 min later. For dynamic imaging, a sequence of serial images is initiated exactly at the time of radiopharmaceutical injection (see Dynamic image acquisition below).

Emission image acquisition typically ranges from 6 to 15 min and aims at collecting 5 to 15 million total counts depending on the body site.

As an alternative, the patient can be removed from the PET scanner after acquisition of the transmission images. Before leaving the scanner, careful identification of the patient's position in the scanner is essential in order to exactly reposition the patient in the scanner for emission imaging.

Radiation Dosimetry in Children (5 year old)

| Radiopharmaceutical | Administered Activity | Organ Receiving the Largest Radiation Dose* | Effective Dose* |
|--------------------------------|-----------------------|---|-----------------|
| | MBq/kg (mCi/kg) | mGy (rad) | mSv (rem) |
| 18-fluoro-2-deoxyglucose (FDG) | 5 – 10 i.v. | 0.48 bladder | 0.073 |
| | (0.15 – 0.30) | (1.8) | (0.27) |

*Per MBq (per mCi)

¹ICRP 53, page 76

A total of 30–60 min are allowed for the metabolic uptake phase of FDG. The patient is asked to void prior to being repositioned in the scanner for acquisition of the emission images. As mentioned above, some PET systems allow the acquisition of the transmission images following the emission images.

Semiquantitative estimate of tumor metabolism (SUV, DUR, DAR, etc.) is based on relative lesion radioactivity normalized to injected dose and body weight. This requires a static emission image acquired typically at 30 min (images obtained after FDG reaches plateau concentration). In addition, it requires the total dose of FDG administered, the patient's weight or the patient's height for measurement of lean body mass or both for measurement of body surface area. A calibration factor is needed (see below in quantitative estimates of tumor metabolism). This measurement can be corrected for blood glucose concentration.

Dynamic image acquisition is required for the determination of metabolic rates of tumors. After the transmission image (as described above), a sequence of serial images is initiated precisely at the time of the FDG administration and continues for 60 to 90 min.

Quantitative or semiquantitative estimates of tumor metabolism may require measurements of the arterial input function, determinations of the plasma FDG and glucose concentrations, the total dose of the administered FDG and the patient's height and body weight so that the body surface area can be estimated. In addition, a calibration factor is needed between scanner events in terms of (counts/pixel/sec) and in vitro measured activity concentrations in (counts/ml/sec). This can be accomplished by imaging a cylindrical phantom with a known concentration of a positron emitter and by measuring the activity of an aliquot of the cylinder solution in a well counter.

- b. Whole body imaging can be obtained with correction for photon attenuation which requires acquisitions of transmission images. Elimination of image artifacts requires the exact repositioning of each level of the patient during the acquisitions of both the transmission and emission whole body images.

2. Acquisition parameters for FDG imaging gamma cameras equipped for coincidence detection type positron imaging.

- a. Limited Field Tomographic Images: As with conventional PET tomographs, the patients follow the same preparation guidelines. FDG images are acquired over a 30–45 min period with three degree sampling. The energy window used is $511 \text{ keV} \pm 10\%$.
- b. Whole Body Planar Imaging: Anterior and posterior views are generated. A scanning speed to achieve 450,000 to 1,000,000 counts for each view is recommended.

F. Interventions

A urinary catheter, hydration and a diuretic may be helpful to eliminate confusing urinary tract activity, which may confound the interpretation of local FDG accumulation in the pelvis or abdomen.

G. Processing

1. Processing images acquired with dedicated PET scanners:

- a. Standard Transaxial Images: the data are reconstructed in the form of transaxial 128×128 pixel images or a pixel size of 4–5 mm. A final image resolution of 9–11 mm full width at half maximum typically yields images of adequate resolution and noise. (Some institutions employ a Shepp-Logan filter with a cut off frequency of 0.1 cycles per pixel.) The image sets can be re-oriented into coronal and/or sagittal slices. The contiguous transaxial and/or coronal or sagittal slices are then examined by visual inspection.

Estimates of metabolic rates of tumors, either quantitative or semiquantitative, are obtained by assigning regions of interest to the tumor and the blood pool on the dynamically acquired images. The resulting time activity curves are then fitted with a tracer compartment model or submitted to graphical analysis in order to derive the rate of phosphorylation of F-18-2-deoxyglucose.

For semiquantitative or quantitative studies, accurate calibration of scanner counts to well counter counts is needed; therefore, a cylindrical type calibration should be performed on that day or at regular intervals, typically once or twice a week. The dose injected into the patient should also be recorded as accurately as possible.

- b. Whole Body Images, attenuation corrected and non-attenuation corrected: the sequentially recorded sets of images for each bed position are corrected for radionuclide de-

cay, rearranged into various projection images, reconstructed into a stack of transaxial images, and resliced into a set of coronal whole body images. The number of contiguous whole body coronal slices may range from 15 to 45. Simultaneous computer displays of coronal, sagittal and transaxial cuts, as well as rotating projection images, aid in more precisely localizing the foci of abnormal tracer accumulations, as well as in separating normal physiologic from abnormal pathologic radiopharmaceutical accumulations.

2. Processing of gamma camera coincidence detection data generally employs iterative reconstruction techniques. Refer to camera manufacturer's recommendations for best choices of iterations, subsets and smooths.

H. Interpretation Criteria

1. When other imaging data are available, correlation may be helpful to more accurately localize the lesions.
2. Normal physiologic uptake of FDG can be seen in the brain, myocardium (where the uptake appears in some patients despite prolonged fasting), liver, spleen, stomach, intestines, kidneys and urine.
3. Increased uptake of FDG can be seen in neoplasms, healing surgical wounds, granulomatous tissue, infections and other inflammatory type tissue.
4. Quantitative and semiquantitative estimates may be helpful in identifying malignant lesions.

I. Reporting

The report should include all pertinent information, including name of patient and another identifier, such as birthdate, social security number or hospital or office identification number; name of the referring physician(s) or other health care provider; name or type of examination; dates of examination and the transcription; time of the examination, if relevant; radiopharmaceutical, including administered activity and route of administration; and patient history, including reason for requesting the study.

1. Body of the report

a. Procedures and Materials

Include in the report a description of the PET imaging acquisition (i.e. transmission and emission imaging), procedure performed such as placement of intravenous line, hydration, insertion of Foley catheter (size of catheter), administration of lasix (amount and time), and the area imaged. If

sedation is performed (mainly for brain imaging in children), briefly describe the procedure and state type of medication and time of sedation in relation to the radiotracer injection. State patient condition at the conclusion of the PET imaging study (especially if patient was sedated).

b. Findings

Describe location and intensity of abnormal FDG uptake in relation to normal comparable tissues. State quantitative or semiquantitative measures of lesion FDG uptake, if performed.

c. Limitations

Where appropriate, identify factors that can limit the sensitivity and specificity of the examination (i.e. small lesions, inflammatory process).

d. Clinical Issues

The report should address or answer any pertinent clinical issues raised in the request for imaging examination.

e. Comparative Data

Comparisons with previous examinations and reports when possible, are a part of the radiologic consultation and report.

2. Impression (Conclusion or Diagnosis)

- a. Precise diagnosis should be given whenever possible.
- b. A differential diagnosis should be given when appropriate.
- c. When appropriate, recommend follow-up and additional diagnostic studies to clarify or confirm the impression.

J. Quality Control

1. Radiopharmaceuticals

See the *Society of Nuclear Medicine Procedure Guideline for Use of Radiopharmaceuticals*.

2. Instrumentation

See the *Society of Nuclear Medicine Procedure Guideline for PET Imaging* (to be developed).

K. Sources of Error

1. Residual bowel and/or urinary tract activity may cause both false positive and false negative abdominal examinations.
2. Local inflammatory disease may have increased FDG uptake, especially granulomatous processes.
3. Chemotherapy and radiation therapy may decrease tumor uptake of FDG.
4. Physiologic uptake of FDG may be seen in the thymus, especially in younger patients.
5. Increased FDG uptake in the pulmonary parenchyma can be seen in radiation pneumonitis and in the pleura after radiation

- therapy.
6. Physiologic uptake of FDG may occur in the paraspinal muscles, and in other skeletal muscles.
 7. Images reconstructed without attenuation correction may sometimes have the appearance of prominent peripheral body or skin activity.
 8. Healing surgical wounds may have increased FDG activity up to 6 mo after surgery.
 9. Stimulation of FDG marrow uptake can occur in patients undergoing therapy with GCSF.

V. Issues Requiring Further Clarification

Typical instrumentation for this procedure is the PET scanner, a tomographic imaging device which simultaneously detects a pair of annihilation photons following positron decay for creation of the emission image. The use of modified gamma cameras has shown promise, but additional work needs to be completed to establish the value and role of these instruments for this procedure. These modified gamma cameras detect positron emissions by coincidence detection of their annihilation photons in a process similar to dedicated PET scanners, but at a much lower count rate. Resolution is, therefore, lower than dedicated PET. A third method for positron tomography, treating positron emitting radiopharmaceuticals as if they were single-photon tracers, and employing extra-high energy collimators to perform SPECT imaging, is feasible but may be too low in resolution for accurate FDG imaging in oncology.

VI. Concise Bibliography

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VIII. Disclaimer

The Society of Nuclear Medicine has written and approved guidelines to promote the cost-effective use of high quality nuclear medicine procedures. These generic recommendations cannot be applied to all patients in all practice settings. The guidelines should not be deemed inclusive of all proper procedures or exclusive of other procedures reasonably directed to obtaining the same results. The spectrum of patients seen in a specialized practice setting may be quite different than the spectrum of patients seen in a more general practice setting. The appropriateness of a

procedure will depend in part on the prevalence of disease in the patient population. In addition, the resources available to care for patients may vary greatly from one medical facility to another. For these rea-

sons, guidelines cannot be rigidly applied.

Advances in medicine occur at a rapid rate. The date of a guideline should always be considered in determining its current applicability.

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